Hermit Mine Ground-Water Conditions
Mohave County, Arizona For Energy Fuels
Nuclear, Inc.   Denver, Colorado

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HERMIT MINE
GROUND-WATER CONDITIONS
MOHAVE COUNTY, ARIZONA
FOR
ENERGY FUELS NUCLEAR, INC.
DENVER, COLORADO

Dames & Moore

Prepared By:

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March 20, 1987

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March 20, 1987

Energy Fuels Nuclear, Inc.
One Tabor Center, Suite 2500
1200-17th Street
Denver, Colorado 80202

Attention: Mr. William J. Almas

Re: Hermit Mine
Ground-Water Conditions
Mohave County, Arizona

Gentlemen:

We are pleased to submit our report on Ground-Water Conditions at the Hermit Mine.

We would be pleased to discuss the report with you and to respond to any questions or comments you may have.

Very truly yours,

DAMES & MOORE

Richard L. Harlan djb

Richard L. Harlan
Associate/Senior Hydrogeologist

RLH:djb

Enclosures

HERMIT MINE

GROUND-WATER CONDITIONS

MOHAVE COUNTY, ARIZONA

Prepared For:

ENERGY FUELS NUCLEAR, INC.

Denver, Colorado

By:

DAMES & MOORE

Golden, Colorado

March 20, 1987

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

SUMMARY AND CONCLUSIONS

The Hermit Mine is a proposed underground uranium mine, located approximately 22 miles south-southwest of the town of Fredonia in Mohave County, Arizona. The mineralized zone to be mined is within a collapse breccia pipe which will be accessed by a 1,100 foot vertical shaft to be located outside the ore body, and by extending horizontal drifts into the ore body.

The mine site is located on the Kanab Plateau which is part of the Grand Canyon section of the Colorado Plateau physiographic province. This section of the Colorado Plateau is characterized by flat to gently-sloping plateaus and mesas abruptly dissected by deep canyons. Geologically, the region as a whole is characterized by a thick sequence of flat to gently-dipping sedimentary rocks. In the Grand Canyon area, the sedimentary sequence ranges from about 3,500 to 4,500 feet thick and overlies highly-deformed Precambrian sedimentary, metamorphic, and igneous rocks.

Throughout much of the Colorado Plateau, the regional ground-water table is deep and controlled largely by the elevation of the Colorado River and its major tributaries which are deeply incised. In the vicinity of the Hermit Mine, the regional water table is at a depth greater than 2,000 feet and approximately 1,000 feet below the proposed depth of mining.

Perched ground-water conditions occur locally within the sedimentary sequence above the regional water table. These perched aquifers, however, are typically discontinuous and frequently not capable of being produced on a sustained-yield basis due to the low rates of natural ground-water recharge and their limited lateral extent.

At the Hermit Mine site, perched ground-water conditions have been identified during exploratory drilling within the Coconino sandstone immediately above its contact with the underlying Hermit shale and within the Toroweap limestone. Other perched ground-water zones also may be anticipated to occur as isolated or discontinuous lenses within the Toroweap and Kaibab limestones. These perched zones may yield small quantities of water to the mine workings as they are penetrated. The experience at the Hack Canyon and Pigeon Mines, which are located in the same general area, has been that rates of ground-water inflow to the mine workings decrease with time and generally cease within a period of several months. Parametric studies have further shown that based on the observed rates of ground-water inflow at the Hack Canyon and Pigeon Mines, the "effective" radius of influence as a result of drainage into the mine workings will be small and is typically less than a few thousand feet.

The mine plan for the Hermit Mine calls for extraction of uranium ore from an approximate 600-foot vertical zone within the breccia pipe. The final depth of mining, however, will be nearly 1,000 feet above the regional ground-water table which is within the Redwall-Muav limestone aquifer. The Redwall-Muav aquifer is the upper-most aquifer of regional

importance capable of providing a continuous water supply of even a few gallons per minute. Following cessation of mining, the rate of ground-water inflow to the mine workings will depend on the hydraulic transmission and storage characteristics of the overlying strata and the rate of natural ground-water recharge. As the mine working will be above the regional ground-water table, continued inflow and partial filling of the mine would result in a potential for downward percolation and recharge to the underlying strata and the Redwall-Muav aquifer system. Although a potential exists for downward water migration, the likelihood of significant downward flow is extremely small due to the extensive and complete recementation of the breccia pipe during and following mineralization. Visual observations within both the Hack Canyon and Pigeon Mines have shown the absence of open fractures or joints within the pipe and that essentially all of the voids within the rubblized collapse zone have been filled with a fine-grained matrix comprised mainly of carbon-aceous materials. As a result, the breccia pipe and the area immediately surrounding the pipe are effectively impermeable. This has been confirmed by laboratory tests on core samples from the Canyon Mine prospect. Laboratory tests on rock core samples from the breccia pipe at the Canyon Mine prospect, which is located on the South Rim of the Grand Canyon, indicates that the hydraulic conductivities of the rock mass within and adjacent to the pipe is less than 1×10^{-8} cm/sec. This is consistent with observed conditions in operating mines on the North Rim, specifically the Hack Canyon and Pigeon Mines.

Because of the physical separation between the bottom of the mine and the regional water-table and the potential ameliorating effects of the intervening argillaceous strata, no measurable effects on ground-water quality or quantity are expected to occur as a result of the mining activities.

1.0 INTRODUCTION

The Hermit Mine is a proposed underground uranium mine. The ore deposit is located within a breccia pipe which was located in 1985 and confirmed by exploratory drilling by Energy Fuels Nuclear, Inc. (EFN) . The site is located on unpatented lode mining claims, approximately 22 miles south-southwest of the town of Fredonia in Mohave County, Arizona (Section 17, Township 39 North, Range 4 West, Gila and Salt River Meridian).

In this report, existing geologic and ground-water conditions in the Hermit Mine area are addressed. A discussion is also presented on the hydrogeological characteristics of other breccia pipe mines in the general vicinity and the potential hydrogeological impacts as a result of the proposed mining activities.

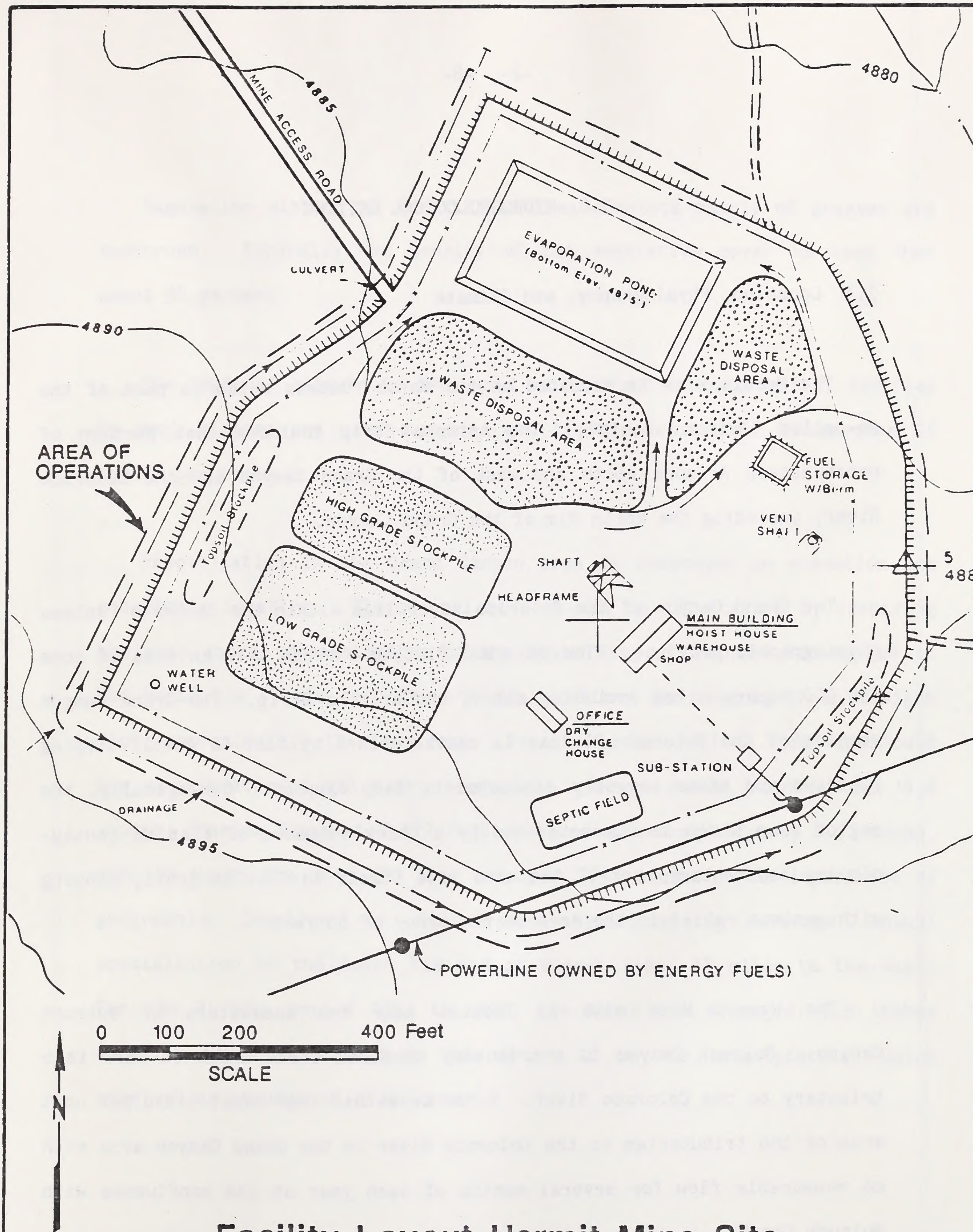
2.0 PROJECT DESCRIPTION

The Hermit Deposit is a uranium ore deposit located within and immediately adjacent to a collapse breccia pipe. The deposit will be mined by sinking a vertical shaft approximately 1,100 feet below the existing ground surface. The shaft will be located adjacent to but outside of the zone of mineralization. The deposit will be mined by extending horizontal drifts into the ore body and mining out the mineralized core of the breccia pipe.

Surface facilities at the mine site will include the headframe, combined hoist, compressor, warehouse and maintenance building and office/mine dry facility. A one-and-a-half mile access road will be constructed to connect the mine site with the existing Mount Trumbull Road. The proposed physical layout of the surface facilities at the Hermit Mine site is shown on Figure 1.

The uranium ore produced by the mine will be temporarily stored in a lined area at the mine site and trucked to an existing mill at Blanding, Utah. No ore processing will be carried out at the mine site.

Plans call for the completion of a water well into the Redwall-Muav aquifer to supply the water requirements for both mining operations and sanitary purposes. The proposed depth of the water-supply well to be located onsite is 2,800 to 3,000 feet.



Facility Layout Hermit Mine Site

Dames & Moore

Figure 1

3.0 HYDROGEOLOGICAL SETTING

3.1 Location, Physiography, and Climate

The Hermit Mine is situated on the Kanab Plateau which is part of the so-called "Arizona Strip". The Arizona Strip includes that portion of northwestern Arizona north and west of the Grand Canyon and the Colorado River, including the North Rim of the Grand Canyon.

The Grand Canyon of the Colorado River lies within the Colorado Plateau physiographic province. The Colorado Plateau extends over an area of some 130,000 square miles including all of the Arizona Strip. The Grand Canyon section of the Colorado Plateau is characterized by flat to gently-sloping plateaus and mesas abruptly dissected by deep canyons. Geologically, the region as a whole is characterized by a thick sequence of flat to gently-dipping sedimentary rocks. The mine site itself is flat to gently sloping with maximum relief in the area on the order of 80 feet.

The Hermit Mine site is located near the headwaters of Bulrush Canyon. Bulrush Canyon is a tributary to Kanab Creek which in turn is a tributary to the Colorado River. Kanab Creek has the lowest yield per unit area of the tributaries to the Colorado River in the Grand Canyon area with no measurable flow for several months of each year at its confluence with Bulrush Creek.

Vegetation within the Hermit Mine area consists mainly of grasses and sagebrush. Typically the density of the vegetative cover is less than about 50 percent.

The regional climate is semi-arid to arid and is continental, typified by cool winters and warm summers, and light precipitation (less than 15 inches per year).

Precipitation in the Grand Canyon area is dependent on elevation and geographic location. Elevational effects can be illustrated by comparing the mean annual precipitation on the South Rim, at Phantom Ranch, and on the North Rim (Table 1). These three locations lie roughly on a straight line, approximately 13 miles long. For the period 1951 to 1980, the South Rim at elevation 6,970 feet received an average annual rainfall of 14.6 inches; Phantom Ranch at 2,570 feet received an average of only 8.7 inches, and the North Rim at 8,400 feet received 25.5 inches. The importance of geographic location is illustrated by comparing average annual precipitation on the South Rim and at Desert View, 18 miles to the east. For the 21-year period 1961 to 1982, the South Rim averaged 15.5 inches annually compared to Desert View which is on the same plateau, which received an average of 13.0 inches.

TABLE 1

AVERAGE MONTHLY PRECIPITATION AT GRAND CANYON AREA LOCATIONS

	Elevation (ft)	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	YEAR
South Rim[1]	6,785	1.49	1.26	1.61	0.92	0.62	0.58	1.49	1.96	1.07	1.20	1.01	1.45	14.65
Desert View[2]	7,400	1.16	1.08	1.54	0.75	0.71	0.28	1.29	1.53	1.04	1.43	0.97	1.54	13.32
Phantom Ranch[1]	2,570	0.85	0.65	0.92	0.46	0.36	0.35	0.82	1.20	0.76	0.82	0.74	0.78	8.69
North Rim[1]	8,400	4.43	2.82	3.69	1.57	1.00	0.68	1.95	2.37	1.33	1.61	1.48	2.55	25.47
Mt. Trumbull[3]	5.600	0.78	0.62	0.81	0.56	0.52	0.48	1.72	1.89	0.98	0.74	0.72	0.83	10.63
Lees Ferry[1]	3,210	0.43	0.34	0.51	0.38	0.33	0.23	0.83	0.86	0.50	0.60	0.53	0.46	5.99
Supai[4]	3,205	0.65	0.69	0.85	0.38	0.42	0.28	1.10	1.41	0.63	0.64	0.77	0.67	8.48
Pierce Ferry[5]	3,860	0.90	1.00	1.37	0.79	0.53	0.35	0.88	1.52	0.78	0.61	1.06	0.95	10.73
Tuweep[1]	4,775	1.23	0.99	1.26	0.67	0.56	0.47	1.39	1.71	0.85	0.86	0.87	1.24	12.08

1. Period of Record 1951-1980
2. Period of Record 1960-1982
3. Period of Record 1948-1977, station now closed
4. Period of Record 1956-1982
5. Period of Record 1963-1982

Notes: Station title of north rim is Bright Angel RS. There are many gaps in the record for the north rim. Station title at south rim is Grand Canyon NP 2. Complete title for Pierce Ferry 17 SSW.

Practically all of the winter precipitation on the North and South Rims of the Grand Canyon occurs as snow. On the Coconino Plateau, south of the Grand Canyon, snow usually melts shortly after it falls, while on the Kaibab Plateau on the north side, much of the snow accumulates until spring when melting snow and rainfall recharge the underlying ground-water system and contribute to high seasonal runoff. The high seasonal runoff in combination with the rapid runoff during summer high-intensity, short-duration rainfall events effectively limits the amount of precipitation available for ground-water recharge within Kaibab Plateau.

3.2 Regional Geology

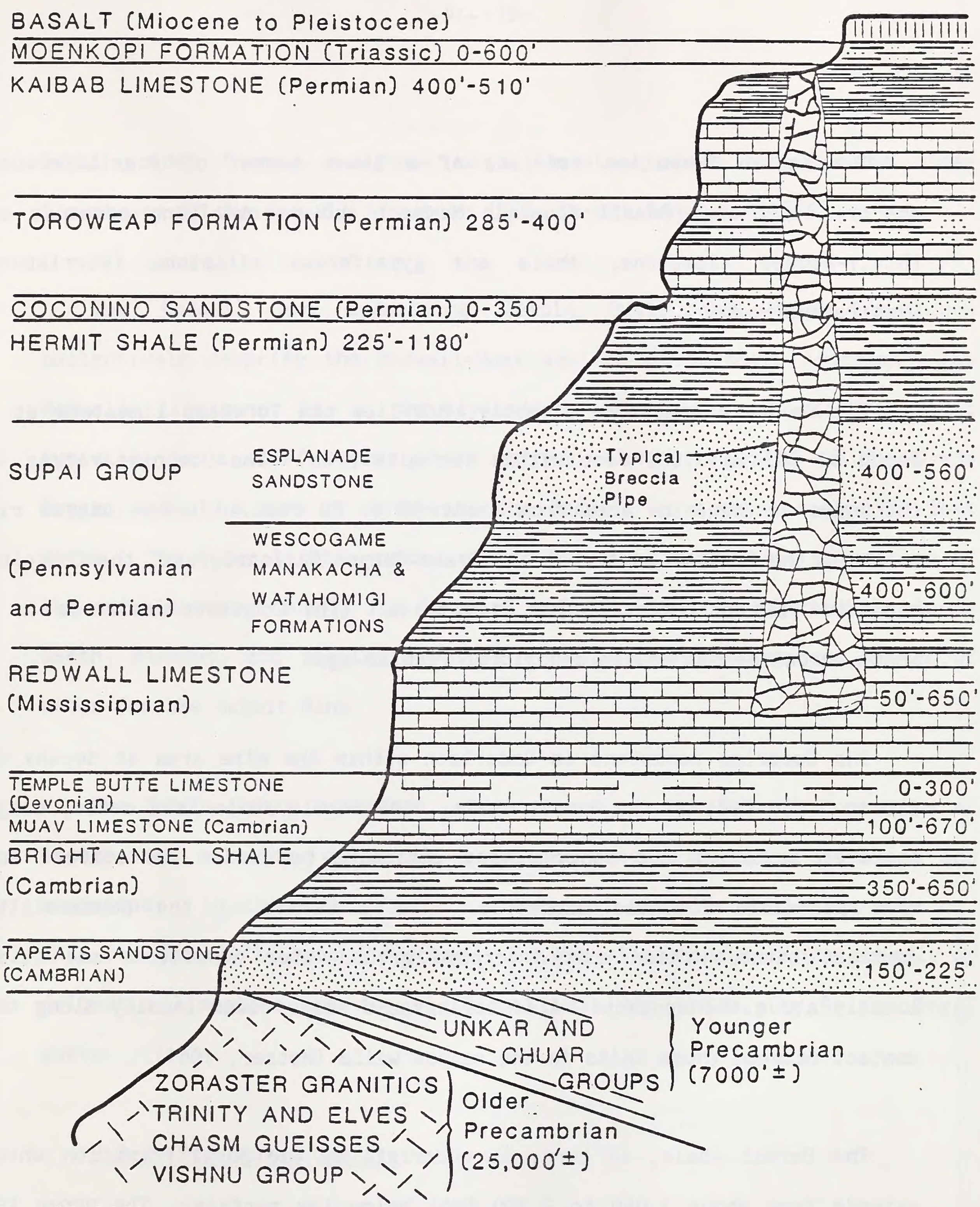
The Kaibab Plateau, on which the Hermit Mine prospect is located, is underlain by a thick sequence of horizontal to gently dipping Paleozoic rocks (570 to 225 million years before present). The sedimentary sequence, which is exposed in the walls of the Grand Canyon, ranges from about 3,500 to 4,500 feet thick and overlies highly-deformed Precambrian (older than 570 million years before present) sedimentary, metamorphic, and igneous rocks. The Precambrian rocks form the basement complex which for practical purposes constitute the lower limit of ground-water occurrence and movement (National Park Service, 1984). While some ground water undoubtedly occurs within the Precambrian, the quantities and its significance are small compared to those within the overlying sedimentary strata.

3.2.1 Stratigraphy

The generalized stratigraphy in the Hermit Mine site area is shown on Figure 2 and discussed below. Section 3.2.2 addresses the structural geology; Section 3.2.3 describes the occurrence and nature of breccia pipes, within the Colorado Plateau and their hydrogeological characterization.

In the Hermit Mine site area, the uppermost formation is the Moenkopi of Triassic age. The Moenkopi consists of red siltstone and claystone which outcrop directly at the surface or underlie the surface at a shallow depth. The formation in the mine site area ranges from about 100 to 500 feet in thickness.

The Moenkopi is underlain by the Kaibab and Toroweap limestones. These formations dip gently to the north and are exposed in the walls of the Grand Canyon. In the Hermit Mine area, the aggregate thickness of the Kaibab and Toroweap Formations is 600 to 800 feet. In the vicinity of the Hack Canyon and Pigeon Mines, the Toroweap Formation consists of a basal unit of sandstone and shale approximately 30 feet thick (Seligman Member), a 210-foot thick middle unit of fossiliferous grey limestone (Brady Canyon Member), and an upper, slope-forming unit of about 160 feet of gypsiferous shale and siltstone (Woods Ranch Member).



SOURCES:
- DEPT. OF INTERIOR, 1976, DRAFT ENVIRONMENTAL STATEMENT, GRAND CANYON
- NUEXCO, REPORT 176, APRIL, 1983

Arizona Strip District
Generalized Stratigraphy

Dames & Moore

Figure 2

The Kaibab Formation consists of a lower member of fossiliferous, cherty, limestone (Fossil Mountain Member) and an overlying sequence of thinly-bedded limestone, shale and gypsiferous siltstone (Harrisburg Gypsiferous Member).

The Coconino sandstone directly underlies the Toroweap limestone at a depth of 900 to 1,000 feet within the mine area. The Coconino ranges in thickness in the mine area from about 30 to 50 feet. In the canyon rim north of the visitor center at the Grand Canyon National Park, the Coconino sandstone is approximately 300 feet thick. The Coconino sandstone is a white, cross-bedded eolian deposit of Permian age.

The Coconino sandstone is underlain within the mine area at depths of 930 to 1,050 feet by the Hermit shale. The Hermit shale is a dense, clay-cemented siltstone and behaves as a confining bed under the coarser and more permeable Coconino sandstone. As a result of the permeability contrast between these units, perched ground-water conditions may exist locally above the contact. Also springs and seeps occur locally along the contact between those units in the canyon walls (Metzer, 1961).

The Hermit shale, in turn, is underlain by the Supai Formation which extends from about 1,050 to 2,300 feet below the surface. The upper few hundred feet of the Supai Formation is the resistant sandstone that resulted in the formation of the inner gorge of the Grand Canyon. The upper Supai Formation and the overlying Hermit shale are the main host rocks for the ore deposit at the Hermit prospect. The lower portion of the

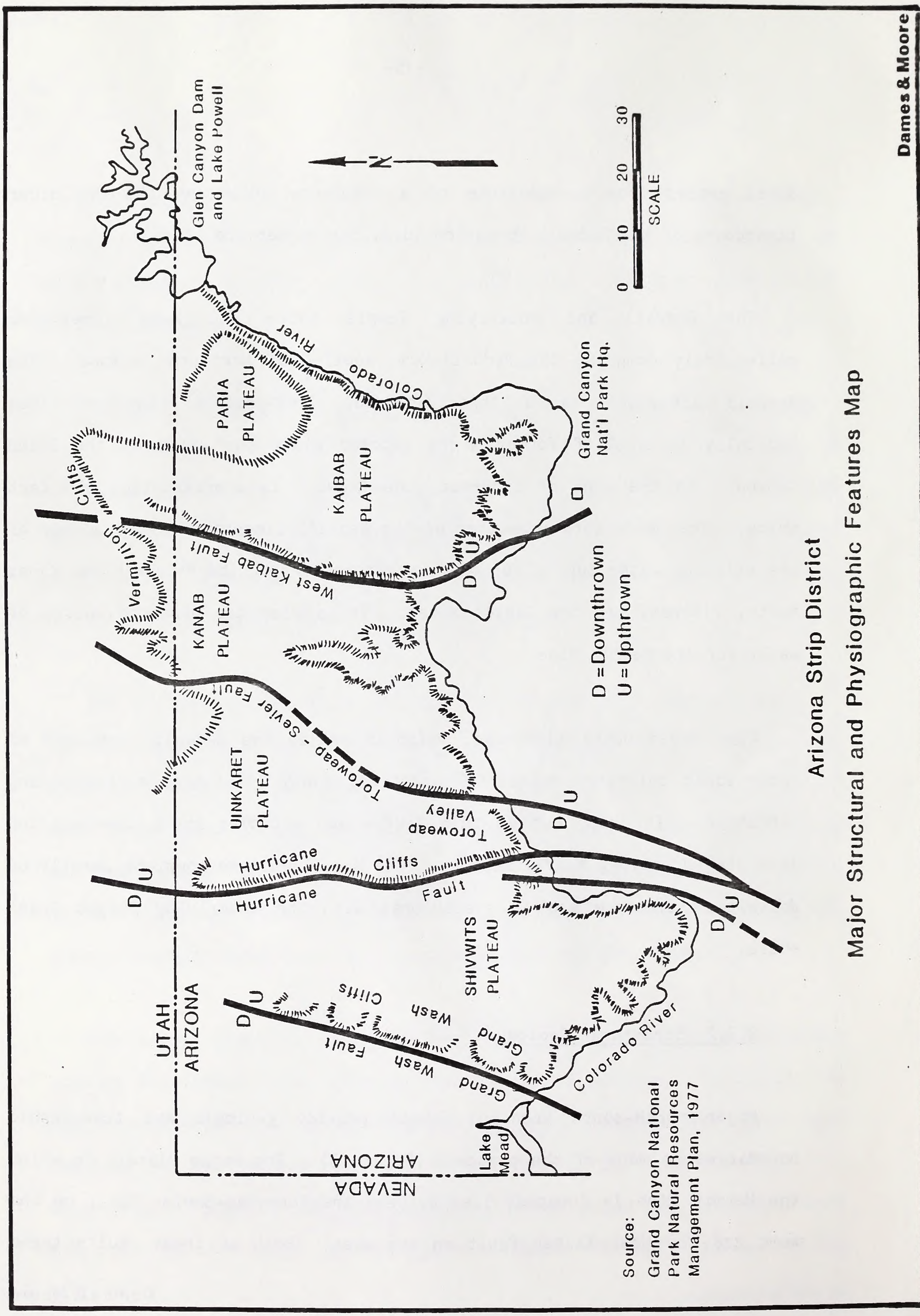
Supai grades from a sandstone to a limestone which overlie the older limestones of the Redwall Formation (U.S. Forest Service, 1985).

The Redwall and underlying Temple Butte and Muav limestones collectively comprise the Redwall-Muav aquifer of Northern Arizona. The Redwall limestone is a thickly-bedded, fine-grained limestone that typically is a cliff former where exposed along the walls of the Grand Canyon. In the area of interest, the Redwall is approximately 450 feet thick. The upper karstic member of the Redwall limestone is the source of the existing water supply for on-going operations at the Pigeon Mine, Kanab North, Pinenut, and the Canyon Mines. It is also the proposed source of water for the Hermit Mine.

The Temple Butte limestone, which underlies the Redwall, consists of interbedded dolomite, dolomitic sandstone, sandy limestone, siltstone and sandstone. It crops out as thin ledges and occupies small channels cut into the underlying Muav limestone. The Muav limestone consists chiefly of dolomitic limestone and is gradational with the underlying Bright Angel shale.

3.2.2 Structural Geology

Major north-south trending faults provide geologic and topographic boundaries to many of the plateaus (Figure 3). The Kanab Plateau on which the Hermit Mine is located, lies between the Toroweap-Sevier Fault on the west and the West Kaibab Fault on the east. Both of these faults trend



Arizona Strip District

Major Structural and Physiographic Features Map

Dames & Moore

Figure 3

north-northeast with movement on the order of hundreds of feet. The West Kaibab Fault and the East Kaibab Monocline form the boundaries of the Kaibab upwarp (Kaibab Plateau), topographically the highest of the area. The East Kaibab Monocline and the Vermillion Cliffs intervene between the Kaibab Plateau and the Paria Plateau to the northeast. The Kanab Valley Fault bisects the Kanab Plateau.

Movements along many of the faults began in the Miocene, but much of the activity peaked during Pliocene time. The faults are thought to be related to underlying Precambrian zones of weakness. Numerous smaller faults and folds are also present; these generally trend north, northwest, or northeast.

3.2.3 Breccia Pipes

Roughly cylindrical, pipe-like collapse structures, termed breccia pipes, are common geologic features across the southern portion of the Colorado Plateau. The breccia pipes are relatively small in diameter, generally less than 500 feet, but may be thousands of feet deep. The pipes contain broken, rubbled rock from surrounding formations encircled by a series of concentric ring fractures. The more-permeable annular fault ring and the rock debris within the center of the pipe provided a vertical conduit for ascending and/or descending mineralizing fluids. When mineable ore occurs in a pipe, it typically is located in both the annualar fault ring and the central breccia matrix, principally in the Hermit and Supai Formations. Because the pipes are not known to extend below the Redwall

limestone, it is generally held that the pipes resulted from successive chimney collapse of the overlying formations into solution caverns developed within the Redwall limestone:

> "Geologists believe that cavities formed millions of years ago by dissolution of portions of the Redwall limestone [which] created space into which the overlying rock collapsed. The collapse zone propagated its way up hundreds, and in some instances, several thousands of feet in the form of a narrow cylinder or cone. This broken rock or pipe created a favorable environment for mineral deposition" (U.S. Forest Service, 1985).

Subsequent to the formation of the breccia pipes and mineralization, the materials within the pipe and in surrounding areas have been recemented and the void spaces filled with a fine-grained matrix consisting mainly of carbonaceous materials. As a result, the breccia pipe and the area around the pipe is effectively impermeable. Laboratory tests, for example, on rock core from the breccia pipe and surrounding areas at the Canyon Mine, (located south of the Grand Canyon), have shown the rock-mass hydraulic conductivities generally to be less than 1×10^{-9} cm/sec.

3.3 Ground-Water Occurrence and Movement

3.3.1 Colorado Plateau Region

The regional geology of the Colorado Plateau has been studied extensively by the U.S. Geological Survey, Energy Fuels, and others. The occurrence and movement of ground water within the plateau, however, have not been studied in the same level of detail, largely because of the depth

of occurrence throughout much of the region. The regional ground-water table throughout much of the plateau is controlled by the elevation of the Colorado River and its major tributaries which are deeply incised. Throughout much of the area, the depth to the regional water table is several thousands of feet beneath the tops of the plateaus.

Because of the depth of incisement of the Colorado River through the Colorado Plateau, the principal water-bearing zones of interest are exposed in the canyon wall. As a result, ground-water occurrence and ground-water chemistry within the Grand Canyon and its major tributary valleys have been studied in detail. These studies, which are based largely on direct surface observations and measurements, in combination with limited borehole and water-quality information for the plateau region, provide a comprehensive and coherent understanding of the regional hydrogeology both on the North and South Rims of the Grand Canyon.

Metzer (1961) describes the relationship between the geology and ground-water resources along the South Rim of the Grand Canyon and provides preliminary conclusions for quality and rates of recharge and discharge. Because of the similarities in the geology between the North and South Rims of the Grand Canyon, Metzer's conclusions also have direct relevance to the assessment of ground-water conditions and the prediction of the potential effects of mining on the Colorado Plateau, in general, and in the Hermit Mine area, in particular.

Huntoon (1982) reports on the results of investigations on ground-water circulation in the plateau regions adjacent to the Grand Canyon. Based on his studies, Huntoon concludes that the ground-water discharge from these regions occurs mainly to springs in the Grand Canyon. Specifically the major springs issue from the Redwall-Muav aquifer system, which is, as previously noted, the major aquifer system in Northern Arizona. Johnson and Sanderson (1968) also provides a compilation of data on ground-water discharge at springs along the Colorado River within the Grand Canyon.

Loughlin (1983) provides interpretations and conclusions on hydrodynamic conditions at the time of formation of breccia pipes in the Grand Canyon area and for ground-water circulation near important springs. The Grand Canyon National Park Water Resources Management Plan (National Park Service, 1984) provides a summary of hydrogeological and hydrochemical data for the park and adjacent areas.

The geology in combination with the low precipitation/high evapotranspiration losses leads to little water actually infiltrating and percolating downward to the regional water table. Although exact rates of natural ground-water recharge are not known, it is suggested that the rates of natural recharge are probably on the order of several hundredths to a few tenths of an inch per year, at best (Metzer, 1961).

Within the thick unsaturated zone above the regional water table, the sedimentary deposits are generally fine-grained and well cemented, although zones containing coarser sands do exist. A potential exists for perched

ground-water conditions to occur above the regional water table wherever a permeability contrast exists, for example immediately above the contact of the permeable Coconino sandstone with the underlying low permeability Hermit shale. Perched ground water may also be anticipated to occur as isolated or discontinuous lenses within the overlying Toroweap and Kaibab limestones. The existence of localized perched ground-water zones above the regional water table is manifested in isolated springs and seeps along the walls of the Grand Canyon and tributary canyons. The discharge from these perched zones is typically small, that is less than a few gallons per minute, and frequently intermittent.

The experience has been regionally that these isolated perched ground-water zones are not capable of being produced at a sustained rate for any length of time because of their limited areal extent and the slow rates of natural ground-water recharge. Consequently, it can be anticipated that if perched ground-water zones are encountered during mining, they may produce small quantities of water initially, but the yield can be expected to decrease with time and frequently to cease altogether within a period of several weeks or months. This is consistent with observed conditions during mining at the Hack Canyon and Pigeon Mines where aggregate inflow to the mine workings has decreased from about 10 to less than 5 gallons per minute.

3.3.2 Site-Specific Conditions

The proposed mine plan for the Hermit Mine calls for the extraction of uranium ore from an approximate 600 foot interval within the breccia pipe. The ore body would be accessed by construction of a 1,100-foot vertical shaft located outside of the mineralized zone and by extending horizontal drifts into the mineralized zones within the breccia pipe. The final depth of mining will be nearly 1,000 feet above the regional ground-water table which is within the Redwall-Muav limestone aquifer. Consequently, it is not expected that significant ground-water inflow to the mine itself will occur. Isolated zones and some fractures above and in the area of the planned mine workings are known to contain perched ground water. Specifically, perched ground water has been encountered in the Toroweap limestone and within the Coconino sandstone immediately above the top of the Hermit shale. During mine development, these perched ground-water zones may cause water to collect in the mine workings, requiring pumping to the ground surface. It is further expected that as mining progresses the inflow to the mine from any perched zones that are encountered will decrease; resulting in the expectation that the Hermit Mine will be essentially dry in the latter phases as have been the cases in the Hack Canyon and the Pigeon Mines.

The perched ground-water zone within the Toroweap limestone at the location of the proposed Hermit Mine has been developed to provide water for livestock. The well at this location can be produced at about 2 gpm on an intermittent basis only. The potential yield from the perched ground-water zone at the base of the Coconino sandstone is believed to be very small.

3.4 Ground-Water Quality

Existing data on the quality of ground-water inflow to existing mines within the Colorado Plateau are limited primarily because of its infrequent occurrence. The analytical results for a sample collected from the Pigeon Mine in August, 1986 by Energy Fuels together with the results of ground-water samples from wells in the area are summarized in Table 2. A description of the wells listed in Table 2 is given in Table 3.

The Pigeon Mine water sample was collected from the discharge to the main sump at the lowest working level in the mine and represents water that has percolated downward through the workings. The sample, therefore, should be representative of mine water. The water is a strongly bicarbonate type indicating neutral to basic pH conditions within the mine. The sample, however, except for radiochemistry, meets all Primary Drinking Water Standards and exceeds the Secondary Drinking Water Standards only for sulfate (851 mg/l) and total dissolved solids (1,920 mg/l). The radiochemistry for the Pigeon Mine sample is summarized in Table 4.

TABLE 2

SUMMARY OF RESULTS FOR CHEMICAL ANALYSIS FOR GROUND-WATER SAMPLES
FROM WELLS WITHIN THE ARIZONA STRIP
(Constituent Levels Exposed In Mg/L)

Well Name/Ref. No.	Pigeon Mine	Pigeon #4	Hack #10	Hunt #5	Kanab #6	Maximum Allowable Contaminated Level	
Well Reg. No.	Main Sump	503711	640855(1)	503919	509198		
Aquifer	---	RW	BP	K/T	RW	(MCL)	(MCL)
Date Sampled	8/22/86	10/4/82	10/4/82	8/4/83	12/6/85	(2)	(3)
<u>Constituent</u>							
Arsenic	<0.01	<0.02	<0.02	0.028	<0.01	(0.05)	(0.05)
Barium	<0.1	<0.50	0.05	<0.5	<0.05	(1.0)	(1.0)
Cadmium	<0.0001	<0.01	-0.013	<0.005	<0.005	(0.01)	(0.01)
Chromium	<0.001	<0.05	<0.05	<0.01	<0.01	(0.05)	(0.05)
Fluoride	0.07	1.6	1.1	1.2	1.0	(1.4-2.0)	(1.4-2.4)
Lead	<0.001	<0.02	0.21	0.024	<0.02	(0.05)	(0.05
Mercury	<0.00006	<0.002	<0.002	<0.001	<0.001	(0.002)	(0.002)
Nitrates	---	0.086	0.055	0.2	<0.20	(10.0)	(45.0)
Selenium	<0.01	0.0050	<0.01	0.005	<0.005	(0.01)	(0.01)
Silver	<0.0001	<0.02	<0.02	0.02	<0.02	(0.05)	(0.05)
Alkalinity	337.0	245.0	186.5	260.0	204.0	N/A	N/A
Calcium	179.0	142.0	131.0	570.0	435.0	N/A	N/A
Chloride	---	31.3	26.3	18.0	72.0	N/A	500.0
Copper	<0.001	0.01	0.01	<0.05	<0.05	N/A	1.0
Iron	0.05	2.0	<0.05	2.2	<0.1	N/A	0.3
Magnesium	202.0	40.0	59.0	175.0	170.0	N/A	N/A
Manganese	0.05	0.0	0.02	<0.05	<0.05	N/A	0.05
Sodium	99.0	104.0	717.0	25.0	128.0	N/A	N/A
Sulfate	851.0	890.0	3,560.0	2,020.0	1,535.0	N/A	500.0
TDS	1,920.0	---	---	2,980.0	2,570.0	N/A	1,000.0
Zinc	2.5	<0.05	1.11	5.4	<0.05	N/A	5.0
Uranium	0.17						

Aquifer: RW = Redwall/Muav
BP = Breccia Pipe
K/T = Kaibab/Toroweap

(1) Sample was taken after passing through a water softener.
(2) Arizona Department of Health Services.
(3) Federal drinking water standards.

TABLE 3

WATER WELL STATISTICS

WELL NAME/ REF. NO.	REGISTRATION NUMBER	WELL DEPT.	STATIC WATER LEV.	YIELD (GPM)	PRINCIPAL AQUIFER
Pigeon Well/ #4	503711	2,350	1,736	10	Redwall Ls.
Hunt Well+/ #5	503919	660	370	2	Toroweap Fm.
Kanab North Well/#6	509198	2,700	1,470	10	Redwall Ls.
Hack Canyon/ #10	640855	1,475	1,096	5	Breccia Pipe

Note: N/A - Not Available.

\+ - Hunt Well #5 is located at the Hermit Mine Site.

TABLE 4

RADIOCHEMISTRY, PIGEON MINE WATER

Gross Alpha (pCi/l), Total	331 ± 36
Gross Beta (pCi/l), Total	99 ± 17
Radium 226 (pCi/l), Total	39 ± 1.6
Radium 228 (pCi/l), Total	1.4 ± 1.6

4.0 HYDROGEOLOGICAL CHARACTERISTICS OF BRECCIA PIPES

As discussed previously in Section 3.2.3, mineralization in the Hermit Mine area occurs in or near a breccia-pipe structure that cuts vertically through the flat-lying sedimentary strata. Cavities formed millions of years ago by dissolution of portions of the deeper Redwall limestone created cavities which resulted over time in the collapse of the overlying strata. The collapse zone propagated upward through the overlying strata several hundreds of feet forming a cylinder or narrow cone filled with breccia or rock fragments.

Geochemical changes within the breccia zone resulted in cementation of the breccia or broken rock infilling the voids with a fine-grained matrix, and depositing uranium and other minerals including silver and copper. As a result of the primary and secondary mineralization, the breccia zone is denser and less permeable than the surrounding rocks. Laboratory tests on rock core from the Canyon Mine prospect, which is located on the South Rim of the Grand Canyon, confirm the dense nature and low hydraulic conductivity of the material both within the breccia pipe and in the natural materials immediately surrounding the pipe. The results of the laboratory measurements which are summarized in Table 5 indicate that the geologic materials immediately surrounding the pipe are effectively impermeable with measured hydraulic conductivities less than 1×10^{-9} cm/sec. In comparison, the measured hydraulic conductivities for the material from inside the breccia pipe but not within the uranium ore zone range from 2.0

x 10^{-7} to 1.4 x 10^{-6} cm/sec. Measured hydraulic conductivities for three samples taken within the pipe but below the proposed depth of mine were less than 1 x 10^{-8} cm/sec.

TABLE 5

LABORATORY HYDRAULIC CONDUCTIVITY
OF ROCK CORE SAMPLES, CANYON MINE

Sample	Sample Description	Depth Below Ground Surface -Feet-	Hydraulic Conductivity -cm/sec-
1	Sandstone/siltstone-outside pipe	2,020	2.2×10^{-10}
2	Sandstone/siltstone-outside pipe	2,303	1.3×10^{-11}
3	Sandstone/siltstone-outside pipe	2,045	9.4×10^{-11}
4	Sandstone/siltstone-outside pipe	2,059	$<3.4 \times 10^{-13}$
5	Sandstone/siltstone-outside pipe	- SAMPLE FAILED -	
6	Sandstone/siltstone-outside pipe	2,285	1.2×10^{-11}
7	In pipe, but not in uranium ore zone	2,299.25	2.0×10^{-7}
8	In pipe, but not in uranium ore zone	1,381.50	6.1×10^{-7}
9	In pipe, but not in uranium ore zone	1,188.50	1.4×10^{-6}
10	In pipe below 2,000 foot level	2,012	1.6×10^{-9}
11	In pipe below 2,000 foot level	2,073	7.0×10^{-9}
12	In pipe below 2,000 foot level	2,133	4.7×10^{-9}

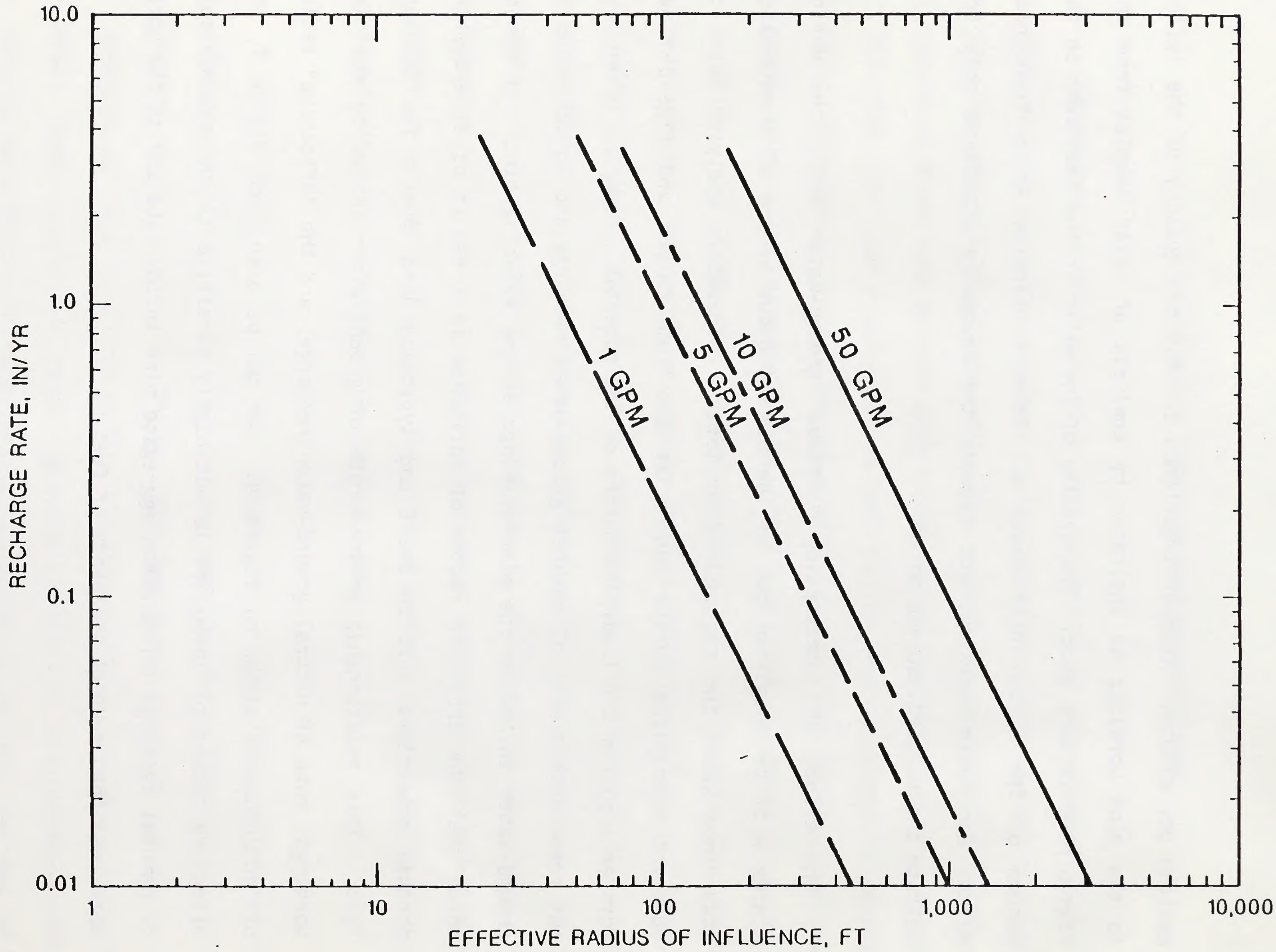
5.0 POTENTIAL IMPACT OF MINING OPERATIONS

Experience to date has shown that the rates of ground-water inflow to the existing mines in the Kanab Plateau decrease with time and are small, that is less than 5 gallons per minute. Following cessation of mining, it can be expected that ground-water inflow to the mine workings will continue and that with time a potential exists for the mine workings to partially fill with water. In that the mine workings are above the regional water table which is believed to be some 1,000 feet below the depth of mining, a potential will exist for downward seepage from the mine to the regional water table. The rates of filling of the mine workings and the rates of downward seepage will depend on the hydraulic transmission and storage characteristics of the overlying, underlying and adjacent strata. The low rates of natural ground-water recharge is evidenced by the limited and localized occurrence of perched ground-water conditions above the regional water table and the fact that the yield from their perched zones generally is not sustainable, even at low pumping rates.

The experience at the Hack Canyon and Pigeon Mines has been that perched ground-water conditions can be expected to be encountered during sinking of the shaft and mining. The aggregate rates of inflow to the workings at both the Hack Canyon and Pigeon Mines, however, have been small, that is less than about 5 gallons per minute. The inflow, which is largely associated with localized perched zones at or near the top of the Hermit shale, has decreased with time and is currently less than a few

gallons per minute. Also of importance is that the quality of the inflow to the mine workings as indicated by analysis of water samples from the Pigeon Mine is very good. The quality of the water in the main sump in the bottom of the Pigeon Mine meets all Primary Drinking Water Standards, except for radiochemistry, and exceeds the Secondary Standards only for sulfate and total dissolved solids.

The effect of intercepting "perched" ground-water conditions during mining will be localized due to the discontinuous nature of ground-water occurrence above the regional water table. Parametric analyses based on observed conditions during mining at the Hack Canyon and Pigeon Mines further supports the localized nature of the potential impacts. Given low, but reasonable rates, of natural ground-water recharge and actual rates of ground-water inflow to the mine workings at the existing mines, it can be shown that the effective radius of influence as a result of intercepting perched conditions will be small and typically less than a few thousand feet. This relationship between rate of ground-water inflow to the mine workings, rate of natural ground-water recharge, and the "effective" radius of influence is shown on Figure 4. As can be seen from Figure 4, the effective radius of influence is not highly sensitive to the assumed rate of natural recharge for a given aggregate mine inflow rate and in the worst case less than several thousands of feet.



Effective Radius of Influence as a Function of Aggregate Mine Inflow and Rate of Ground-water Recharge

Dames & Moore

Figure 4

The proposed depth of mining within the mineralized portion of the breccia pipe at the Hermit site will be approximately 1,000 feet above the regional ground-water table within the Redwall-Muav aquifer. Laboratory tests on rock core from within the breccia pipe but below the depth of uranium mineralization have shown the rock mass to be effectively impermeable. Measured hydraulic conductivities for the non-mineralized portions of the breccia pipe below the depth of mining were less than 1 x 10^{-8} cm/sec. This compares measured hydraulic conductivities of less than 1 x 10^{-9} cm/sec for the altered sandstone and siltstone units adjacent to, but outside of the breccia pipe and measured values of 2.0 x 10^{-7} to 1.4 x 10^{-6} cm/sec for non-mineralized portions of the pipe within the zone of mining.

In summary, recementation of the collapse breccia within the pipe and the alternation and recementation of the sedimentary units immediately around the pipe have resulted in a very low permeability environment. Because of the very low permeabilities and the physical separation, the potential for any direct impact on water quality or quantity within the Redwall-Muav limestone aquifer is negligible.

In addition to these physical factors which limit the potential for water quality or quantity impacts with the Redwall-Muav aquifer, adsorption of heavy metals and radioactive constituents on the surfaces of clays as well as chemical reactions with the rock strata will tend to minimize or eliminate any short-term or long-term potential water-quality impacts.

Thick sequences of argillaceous mudstones and limestones with high adsorptive capacities physically separate the uppermost aquifer within the Redwall-Muav limestones and the proposed depth of mining.

Although regionally, breccia pipes are a common geologic feature within the Colorado Plateau, only a relatively few contain sufficient uranium mineralization to be commercially mineable. These breccia pipes, as discussed, are typically small in diameter - that is less than 300 to 500 feet. Given the existing geologic and hydrogeologic conditions in and in the immediate area of mineralized breccia pipes in the Colorado Plateau, it is highly improbable that the development, and mining of selected breccia pipes such as at the proposed Hermit Mine site will have a measurable or quantifiable impact on ground-water quality or quantity within the Redwall-Muav aquifer. It can be expected that mine development may locally dewater perched ground-water systems which exist within the thick unsaturated zone above the regional water table. Any effect on these perched systems, however, will be limited to the immediate mine area.

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